



Designation: A693 – 16

# Standard Specification for Precipitation-Hardening Stainless and Heat-Resisting Steel Plate, Sheet, and Strip<sup>1</sup>

This standard is issued under the fixed designation A693; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

## 1. Scope\*

1.1 This specification<sup>2</sup> covers precipitation-hardening stainless steel plate, sheet, and strip. The mechanical properties of these steels are developed by suitable low-temperature heat treatments generally referred to as precipitation hardening.

1.2 These steels are used for parts requiring corrosion resistance and high strength at room temperature or at temperatures up to 600°F (315°C). Some of these steels are particularly suitable for moderate to severe drawing and forming in the solution-treated condition. Others are capable of mild forming only. They are suitable for machining in the solution-annealed condition, after which they may be hardened to the mechanical properties specified in this standard without danger of cracking or distortion.

1.3 The values stated in inch-pound units are to be regarded as the standard.

## 2. Referenced Documents

2.1 *ASTM Standards*:<sup>3</sup>

[A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip](#)

[E527 Practice for Numbering Metals and Alloys in the Unified Numbering System \(UNS\)](#)

2.2 *SAE Standard*:

[SAE J 1086 Recommended Practice for Numbering Metals and Alloys \(UNS\)](#)<sup>4</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.17 on Flat-Rolled and Wrought Stainless Steel.

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<sup>2</sup> For ASME Boiler and Pressure Vessel Code applications see related Specification SA-693 in Section II of that Code.

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>4</sup> Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

## 3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification [A480/A480M](#) or as specified in the following:

3.1.1 *Ordering Information*:

3.1.1.1 In addition to the requirements of Specification [A480/A480M](#), the heat treatment (see Section 6) shall be specified on the purchase order if other than the solution-annealed condition is being ordered.

## 4. Materials and Manufacture

4.1 The steel shall be melted by one of the following processes:

4.1.1 Electric furnace (with separate degassing and refining optional),

4.1.2 Vacuum furnace, and

4.1.3 One of the former followed by:

4.1.3.1 Consumable remelting in vacuum, inert gas, or electroslag, or

4.1.3.2 Electron beam refining.

4.1.4 Other commercial melting methods as agreed upon between purchaser and seller are acceptable.

## 5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition specified in [Table 1](#), and shall conform to applicable requirements specified in the current edition of Specification [A480/A480M](#).

## 6. Heat Treatment of Product

6.1 Material of types other than Type UNS S46910 shall be furnished in the solution-annealed condition as noted in [Tables 2 and 3](#) unless otherwise specified by the purchaser on the purchase order.

6.2 Type UNS S46910 shall be furnished in cold-worked condition.

\*A Summary of Changes section appears at the end of this standard

**TABLE 1 Chemical Requirements<sup>A</sup>**

UNS Designation <sup>B</sup>	Type	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Aluminum	Molybdenum	Titanium	Copper	Other Elements <sup>C</sup>	Composition, %	
S17400	630	0.07	1.00	0.040	0.030	1.00	15.0-17.5	3.0-5.0	...	...	...	3.0-5.0	D		
S17700	631	0.09	1.00	0.040	0.030	1.00	16.0-18.0	6.5-7.7	0.75-1.50	...	...	...	...	...	...
S15700	632	0.09	1.00	0.040	0.030	1.00	14.0-16.0	6.5-7.7	0.75-1.50	2.00-3.00	...	...	...	...	...
S35000	633	0.07-0.11	0.50-1.25	0.040	0.030	0.50	16.0-17.0	4.0-5.0	...	2.5-3.2	...	...	...	E	
S35500	634	0.10-0.15	0.50-1.25	0.040	0.030	0.50	15.0-16.0	4.0-5.0	...	2.5-3.2	...	...	...	E	
S17600	635	0.08	1.00	0.040	0.030	1.00	16.0-17.5	6.0-7.5	0.40	...	0.40-1.20	...	...	...	...
S36200	XM-9	0.05	0.50	0.030	0.030	0.30	14.0-14.5	6.5-7.0	0.10	0.30	0.60-0.90	...	...	...	...
S15500	XM-12	0.07	1.00	0.040	0.030	1.00	14.0-15.5	3.5-5.5	...	...	...	2.5-4.5	...	D	
S13800	XM-13	0.05	0.20	0.010	0.008	0.10	12.3-13.2	7.5-8.5	0.90-1.35	2.00-2.50	...	...	...	G	
S45500	XM-16	0.05	0.50	0.040	0.030	0.50	11.0-12.5	7.5-9.5	...	0.50	0.80-1.40	1.50-2.50	...	F	
S45000	XM-25	0.05	1.00	0.030	0.030	1.00	14.0-16.0	5.0-7.0	...	0.50-1.00	...	1.25-1.75	...	H	
S46500	...	0.02	0.25	0.015	0.010	0.25	11.0-12.5	10.8-11.2	...	0.75-1.25	1.50-1.80	...	...	G	
S46910	...	0.030	1.00	0.030	0.015	0.70	11.0-13.0	8.0-10.0	0.15-0.50	3.0-5.0	0.50-1.20	1.5-3.5	...	...	...

<sup>A</sup> Limits are in percent maximum unless shown as a range or stated otherwise.

<sup>B</sup> Designation established in accordance with Practice E527 and SAE J 1086.

<sup>C</sup> The terms Columbium (Cb) and Niobium (Nb) both refer to the same element.

<sup>D</sup> Niobium 0.15-0.45.

<sup>E</sup> Nitrogen 0.07-0.13.

<sup>F</sup> Niobium 0.10-0.50.

<sup>G</sup> Nitrogen 0.01.

<sup>H</sup> Niobium 8 times carbon minimum.

**TABLE 2 Heat Treatment, °F**

UNS Designation	Type	Solution Treatment	Precipitation Hardening Treatment <sup>A</sup>
S17400	630	1925 ± 50°F (cool as required)	900 ± 15°F, 1 h, air cool. 925 ± 15°F, 4 h, air cool. 1025 ± 15°F, 4 h, air cool. 1075 ± 15°F, 4 h, air cool. 1100 ± 15°F, 4 h, air cool. 1150 ± 15°F, 4 h, air cool. (1400 ± 15°F, 2 h, air cool + 1150 ± 15°F, 4 h, air cool).
S17700	631	1950 ± 25°F (cool as required)	1750 ± 15°F, hold 10 min, cool rapidly to room temperature. Cool within 24 h, to -100 ± 10°F, hold not less than 8 h. Warm in air to room temperature. Heat to 950 ± 10°F, hold 1 h, air cool.
		<i>Alternative Treatment:</i>	
		1400 ± 25°F, hold 90 min, cool to 55 ± 5°F within 1 h. Hold not less than 30 min, heat to 1050 ± 10°F, hold for 90 min, air cool.	
S15700	632	1950 ± 25°F (cool as required)	Same as Type 631
S35000	633	1900 ± 50°F (quench)	1710 ± 25°F for not less than 10 min, but not more than 1 h, quench. Cool to not higher than -100°F, hold for not less than 3 h. Temper at 850 ± 15°F, 3 h, air cool, or 1000 ± 15°F, 3 h, air cool.
S35500	634 <sup>B</sup>	1900 ± 25°F (quench)	1750 ± -10°F for not less than 10 min, but not more than 1 h, quench. Cool to not higher than -100°F, hold for not less than 3 h. Temper at 1000 ± 25°F, holding for not less than 3 h.
S17600	635	1900 ± 25°F (air cool)	950 ± 15°F, 30 min, air cool. 1000 ± 15°F, 30 min, air cool. 1050 ± 15°F, 30 min, air cool.
S36200	XM-9	1550 ± 25°F (air cool)	900 ± 10°F, 8 h, air cool.
S15500	XM-12	1900 ± 25°F (cool as required)	Same as Type 630
S13800	XM-13	1700 ± 25°F (cool as required to below 60°F)	950 ± 10°F, 4 h, air cool. 1000 ± 10°F, 4 h, air cool.
S45500	XM-16	1525 ± 25°F (water quench)	900 ± 10°F, 4 h, air cool. or 950 ± 10°F, 4 h, air cool.
S45000	XM-25	1900 ± 25°F (cool rapidly)	900 ± 15°F, 4 h, air cool. 1000 ± 15°F, 4 h, air cool. 1150 ± 15°F, 4 h, air cool.
S46500	...	1875 ± 25°F (cool rapidly to room temperature) followed by subzero cooling within 24 h after solution treatment; -100 ± 10°F, hold not less than 8 h; warm in air to room temperature	900 ± 10°F, 4 h, air cool 950 ± 15°F, 4 h, air cool 1000 ± 15°F, 4 h, air cool 1050 ± 15°F, 4 h, air cool 1100 ± 15°F, 4 h, air cool
S46910 <sup>C</sup>			890 ± 15°F, 4 h, air cool

<sup>A</sup> Times refer to time material is at temperature.

<sup>B</sup> Equalization and over-tempering treatment: 1425 ± 50°F for not less than 3 h, cool to room temperature, heat to 1075 ± 25°F for not less than 3 h.

<sup>C</sup> Furnished in cold-worked condition.

## 7. Mechanical Properties

7.1 The material, as represented by mechanical test specimens, shall conform to the mechanical property requirements specified in **Table 4** and shall be capable of developing the properties in **Table 5** when heat treated as specified in **9.1**.

## 8. Bending Requirements

8.1 Samples cut from the solution-annealed plate, sheet, or strip shall withstand cold bending as specified in **Table 6** without cracking on the outside of the bent portion.

## 9. Heat Treatment of Test Specimens

9.1 Samples cut from the plate, sheet, or strip shall conform to the mechanical properties of **Table 5** when precipitation hardened as specified in **Table 2** and **Table 3**.

## 10. Keywords

10.1 plate; precipitation hardening; sheet; stainless steel; strip

**TABLE 3 Heat Treatment, °C**

UNS Designation	Type	Solution Treatment	Precipitation Hardening Treatment <sup>A</sup>
S17400	630	1050 ± 25°C (cool as required)	482 ± 8°C, 1 h, air cool. 496 ± 8°C, 4 h, air cool. 552 ± 8°C, 4 h, air cool. 579 ± 8°C, 4 h, air cool. 593 ± 8°C, 4 h, air cool. 621 ± 8°C, 4 h, air cool. (760 ± 8°C, 2 h, air cool + 621 ± 8°C, 4 h, air cool).
S17700	631	1065 ± 15°C (water quench)	954 ± 8°C, hold 10 min, cool rapidly to room temperature. Cool within 24 h to -73°C ± 6°C, hold not less than 8 h. Warm in air to room temperature. Heat to 510 ± 6°C, hold 1 h, air cool.
<i>Alternative Treatment</i>			
		760 ± 15°C, hold 90 min, cool to 15 ± 3°C within 1 h. Hold not less than 30 min, heat to 566 ± 6°C, hold for 90 min, air cool.	
S15700	632	1038 ± 15°C (water quench)	Same as Type 631
S35000	633	1038 ± 25°C (quench)	930 ± 15°C for not less than 10 min, but not more than 1 h, quench. Cool to not higher than -73°C, hold for not less than 3 h. Temper at 455 ± 8°C, 3 h, air cool, or 540 ± 8°C, 3 h, air cool.
S35500	634 <sup>B</sup>	1038 ± 15°C (quench).	954 ± 6°C for not less than 10 min, but not more than 1 h, quench. Cool to not higher than -73°C, hold for not less than 3 h. Temper at 538 ± 15°C, holding for not less than 3 h.
S17600	635	1038 ± 15°C (air cool)	510 ± 8°C, 30 min, air cool. 538 ± 8°C, 30 min, air cool. 566 ± 8°C, 30 min, air cool.
S36200	XM-9	843 ± 15°C (air cool)	482 ± 8°C, 8 h, air cool.
S15500	XM-12	1038 ± 15°C (cool as required)	Same as Type 630
S13800	XM-13	927 ± 15°C (cool as required to below 60°C)	510 ± 6°C, 4 h, air cool. 538 ± 6°C, 4 h, air cool.
S45500	XM-16	829 ± 15°C (water quench)	482 ± 6°C, 4 h, air cool. or 510 ± 6°C, 4 h, air cool.
S45000	XM-25	1038 ± 15°C (cool rapidly)	482 ± 8°C, 4 h, air cool. 538 ± 8°C, 4 h, air cool. 621 ± 8°C, 4 h, air cool.
S46500	...	1024 ± 15°C, (cool rapidly to room temperature) followed by subzero cooling within 24 h after solution treatment; -73 ± 6°C; hold not less than 8 h; warm in air to room temperature	482 ± 6°C, 4 h, air cool 510 ± 8°C, 4 h, air cool 538 ± 8°C, 4 h, air cool 566 ± 8°C, 4 h, air cool 593 ± 8°C, 4 h, air cool
S46910 <sup>C</sup>			475 ± 8°C, 4 h, air cool

<sup>A</sup> Times refer to time material is at temperature.

<sup>B</sup> Equalization and over-tempering treatment: 774 ± 25°C for not less than 3 h, cool to room temperature, heat to 579 ± 15°C for not less than 3 h.

<sup>C</sup> Furnished in cold-worked condition.

**TABLE 4 Mechanical Test Requirements in Solution-Treated Condition**

Type		Tensile Strength, max		Yield Strength, max		Elongation in 2 in. or 50 mm, min, %	Hardness, max	
		ksi	MPa	ksi	MPa		Rockwell	Brinell
630	0.015 to 4.0 in. (0.38 to 102 mm)	...	...	...	...	...	C38	363
631	0.010 in. (0.25 mm) and under	150	1035	65	450	...	...	...
	Over 0.010 to 4.0 in. (0.25 to 102 mm)	150	1035	55	380	20	B92	...
632	0.0015 to 4.0 in. (0.038 to 102 mm)	150	1035	65	450	25	B100	...
633	0.001 to 0.0015 in. (0.03 to 0.038 mm), excl	200	1380	90	620	8	C30	...
	0.0015 to 0.002 in. (0.03 to 0.05 mm), excl	200	1380	88	605	8	C30	...
	0.002 to 0.005 in. (0.05 to 0.13 mm), excl	200	1380	86	595	8	C30	...
	0.005 to 0.010 in. (0.13 to 0.25 mm), excl	200	1380	85	585	8	C30	...
	Over 0.010 in. (0.254 mm)	200	1380	85	585	12	C30	...
634 <sup>A</sup>	Plate	...	...	...	...	...	C40	...
635	0.030 in. (0.76 mm) and under	120	825	75	515	3	C32	...
	Over 0.030 to 0.060 in. (0.76 to 1.52 mm)	120	825	75	515	4	C32	...
	Over 0.060 in. (1.52 mm)	120	825	75	515	5	C32	...
XM-9	Over 0.010 in. (0.25 mm)	150	1035	125	860	4	C28	...
XM-12	0.0015 to 4.00 in. (0.038 to 101.6 mm)	...	...	...	...	...	C38	363
XM-13	0.0015 to 4.00 in. (0.038 to 101.6 mm)	...	...	...	...	...	C38	363
XM-16	0.010 in. (0.25 mm) and greater	175	1205	160	1105	3	C36	331
XM-25 <sup>B</sup>	0.010 in. (0.25 mm) and greater	165	1205	150	1035	4	C33	311
S46500	0.140 in. (3.56 mm) and under	160	1105	150	1035	4	C33	...

<sup>A</sup> Solution-treated, equalized, and over-tempered plate only.

<sup>B</sup> XM-25 also furnished to the following minimum properties:

130	895	90	620	4	C25	255
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